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(56) Documents Cited
GB 2302895 A GB 2006853 A EP 0223552 A2
EP 0063519 A2 US 4298077 A

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(54) Apparatus for circulating fluid in a borehole

(57) Apparatus (1) for circulating fluid in a borehole includes a body member (2) adapted to form a portion of a length of drillstring. The body member (2) has a throughbore (14) and a fluid port (3) extending through a side wall of the body member (2). An inner sleeve (12) is movably mounted within the body member (2) for movement between a closed position in which the inner sleeve (12) obturates the fluid port (3) and an open position in which the fluid port (3) is permitted to communicate with the throughbore (14). A pressure differential means to generate a pressure differential across the inner sleeve (12) is provided to move the sleeve (12) from the closed position to the open position in use. In addition, an indexing mechanism (7, 17) couples the inner sleeve (12) to the body member (2) to permit the inner sleeve (12) to be selectively moved between the closed position and the open position and to maintain the inner sleeve (12) in the closed or open position.

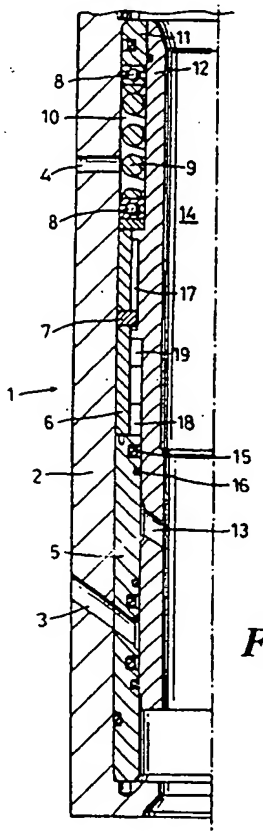

Fig. 1

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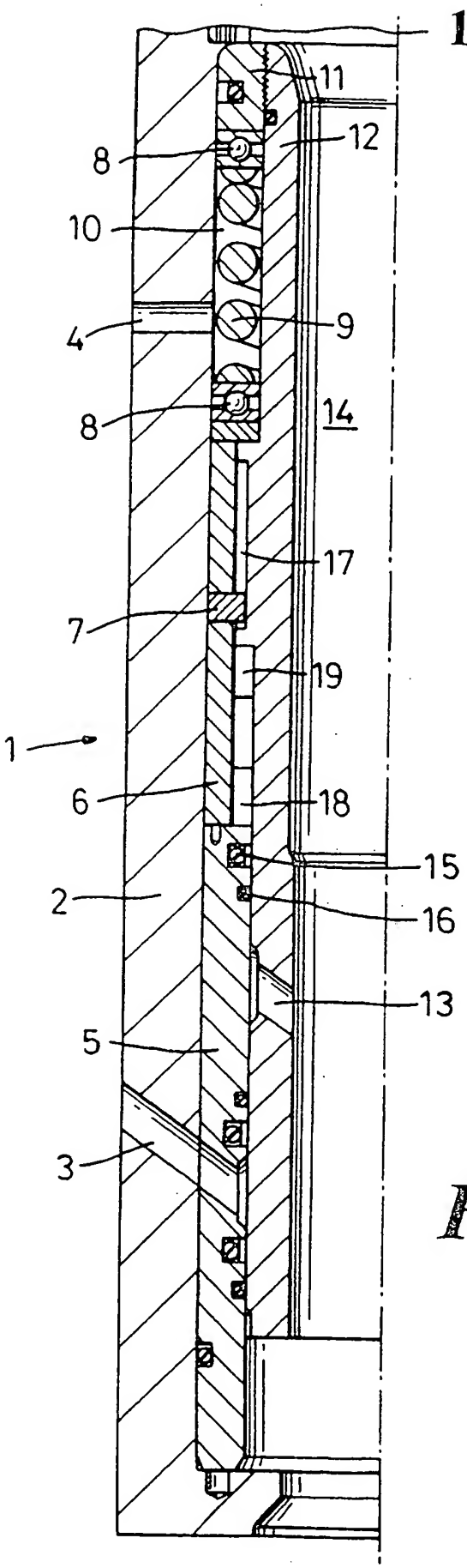
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Fig. 1

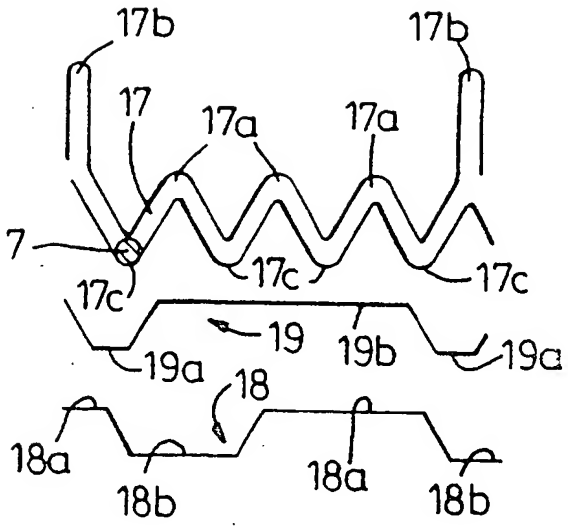
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Fig. 2

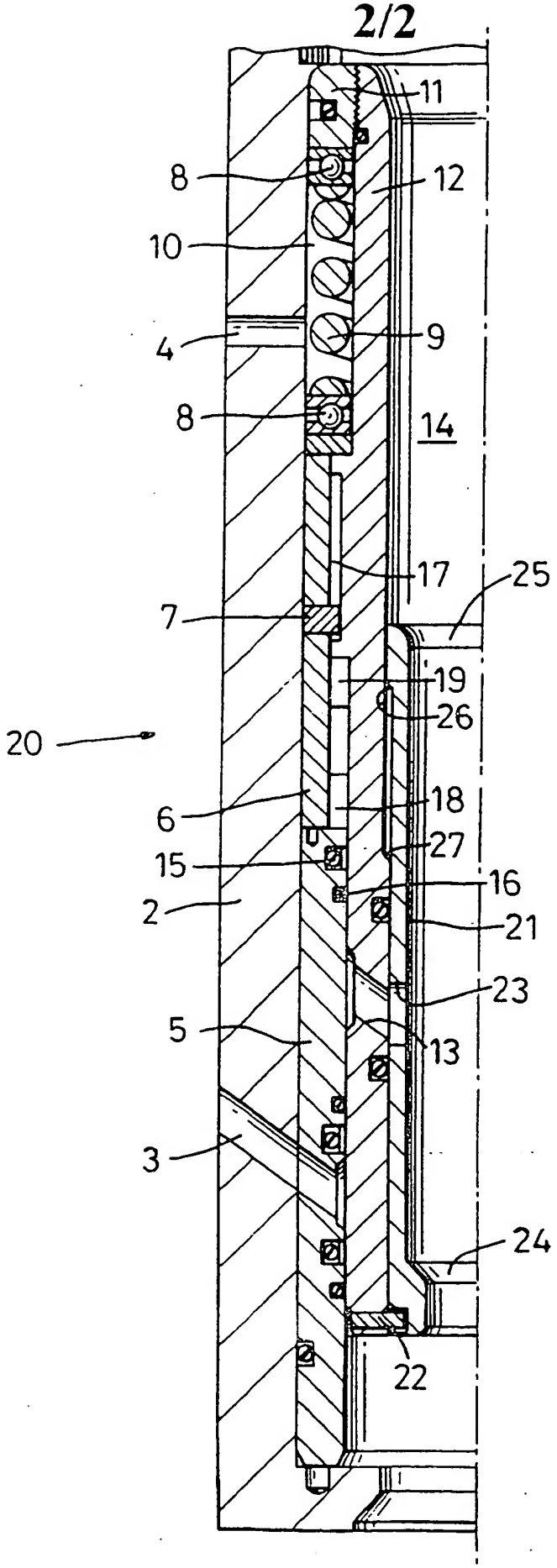

Fig. 3

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"Apparatus for Circulating Fluid in a Borehole"

The invention relates to apparatus for circulating fluid in a borehole and in particular, apparatus for incorporation into a drillstring to circulate fluid to aid removal of drill cuttings from a borehole or to control the influx of hydrocarbons into the borehole, as the borehole is being drilled.

When drilling certain types of wells, commonly extended reach, highly deviated or horizontal wells, it may be difficult to effectively remove drill cuttings from the borehole due to the well and drillpipe geometry. Drill cuttings can accumulate on the low side of the well (in deviated or horizontal wells) and create what is commonly termed a "cuttings bed". It is not uncommon for the cuttings bed to accumulate to an extent that it contacts the drillpipe. This can lead to the drillpipe becoming stuck in the well and so preventing removal of the drillstring from the borehole.

One of the ways of preventing the creation of a cuttings bed is to maintain sufficient velocity of the circulating drilling fluid or mud. If a high enough velocity of drilling fluid is generated in the annulus

between the drillstring and the side walls of the borehole, the cuttings will be flushed upwards out of the hole with the drilling fluid.

However, it is difficult to maintain sufficient velocity of the drilling fluid in highly deviated and horizontal wells, especially at the locations in the borehole in which cuttings tend to accumulate. In addition, the sizing of the drillpipe, bottom hole assembly (BHA) components such as drill collars, mud motors, turbines and the drill bit, and borehole can result in a pressure drop through the system which is high enough to prevent a sufficiently high drilling fluid flow rate being maintained in the annulus between the drillpipe and the side walls of the borehole.

One way of maintaining a sufficiently high flow rate of drilling fluid in the annulus is to incorporate a circulating sub into the drillstring which diverts fluid flow out of the drillstring and into the annulus before the fluid reaches the BHA. Alternatively, the circulating sub may be incorporated into the BHA to divert fluid from the components beneath the sub.

One such tool has fluid flow paths running from the inside of the tool to the outside of the tool and nozzles in the flow path generate flow in the annulus. By changing nozzle size it is possible to generate different flow regimes. However, a problem with this tool is that after the nozzles have been attached to the tool and the tool is inserted into the borehole of the drillstring it is not possible to change the flow paths without removing the drillstring from the borehole. In addition, if a cuttings bed occurs below the tool, the blockage formed by the cuttings bed will tend to force more fluid out of the tool through the

nozzles and therefore reduce the amount of flow going through the drill bit and past the cuttings bed, thereby exacerbating the problem.

Another known tool permits the flow path within the tool to be diverted by dropping a ball down the inside of the drillstring. The ball landing in the tool opens flow ports to permit fluid to be circulated from the inside of the tool to the annulus without passing through the drill bit. Another ball may then be dropped in order to close the flow ports. However, the tool can only function a finite number of times, after which it is necessary to remove the drillstring from the borehole in order to reset the tool. There is also the disadvantage that it is time consuming to pump the balls down the drillstring and into place in the tool. Furthermore, after one ball has been dropped into the tool it is impossible to gain access through the tool to lower sections of the drillstring using wireline run tools. The passage of the ball(s) down the inside of the drill string is sometimes problematic in highly deviated or horizontal wells.

A further existing tool also uses a ball dropped into the drillstring and uses pumping at predetermined rates to move a piston down to expose ports in the tool to permit flow from the inside of the tool directly into the annulus of the borehole. This tool is not locked or fixed in the open or closed position and is therefore reliant on the properties of the drilling fluid (which can vary dramatically) in order to function the tool. Because of this it is not reliable in operation. In addition, the seals of the tool are prone to damage because of the way in which the tool operates and it is not proved a suitable tool in highly deviated and horizontal wells. In addition, as with

the tool discussed above, the balls cause a restriction preventing the use of wireline to access the drillstring below the tool. The balls also have the disadvantage that they are time consuming to pump into place.

In accordance with the present invention, apparatus for circulating fluid in a borehole comprises a body member adapted to form a portion of a length of drillstring, the body member having a throughbore therein, and a fluid port extending through a side wall of the body member; an inner sleeve movably mounted within the body member for movement between a closed position in which the inner sleeve obturates the fluid port and an open position in which the fluid port is permitted to communicate with the throughbore; a pressure differential means to generate a pressure differential across the inner sleeve to move the sleeve from the closed to the open position in use; and, an indexing mechanism which couples the inner sleeve to the body member to permit the inner sleeve to be selectively moved between the closed position and the open position and to maintain the inner sleeve in the closed or open position.

Preferably, the inner sleeve is in the form of a differential pressure piston and the pressure differential means may comprise sealing means to isolate a surface area of the piston exposed to pressure from outside the body member from the surface area of the piston exposed to fluid pressure in the throughbore.

Alternatively, the pressure differential means may comprise a restriction in the throughbore to create a pressure differential within the inner sleeve so that

fluid flow in the throughbore generates sufficient force to move the inner sleeve from the closed position to the open position.

Typically, the inner sleeve obturates the at least one fluid port in the closed position and a fluid port through the inner sleeve aligns with the fluid port in the body member when the inner sleeve is in the open position. Preferably, a number of fluid ports are located circumferentially around the body member and the inner sleeve.

Preferably, the indexing mechanism may include a number of indexing positions and the inner sleeve moves to the next indexing position each time fluid flow into the throughbore is stopped and restarted. Typically, there may be a number of indexing positions in which the sleeve is in the closed position and one indexing position in which the sleeve is in the open position.

Typically, the indexing mechanism comprises a slot or groove formed in the outside surface of the inner sleeve which co-operates with a pin mounted on the body member which engages with the slot.

Typically, the fluid port may include a restriction to generate a pressure differential between the throughbore and the outside of the body member. Preferably, the restriction may be removable or replaceable so that different types or sizes of restriction may be inserted into the fluid port.

The inner sleeve may move in a direction parallel to the longitudinal axis of the throughbore and rotate relative to the body member when moving from the closed position to the open position. Typically, in use, in

the open position the inner sleeve is closer to the drill bit than when the inner sleeve is in the closed position.

The apparatus may also include a secondary inner sleeve which is typically movably mounted within the inner sleeve and may be moved relative to the inner sleeve to permit the fluid port to be closed in the event that it is not possible to return the inner sleeve from the open position to the closed position.

The secondary sleeve may be operated by dropping a spherical member from the surface of the well into the throughbore which permits fluid pressure above the spherical member to move the secondary sleeve to close the fluid port and also to move to a position such that fluid may bypass the spherical member. Preferably, the spherical member is extrudable and may be plastic, elastomeric and/or a rubber material.

Alternatively, the secondary sleeve may be inserted into the apparatus from the surface of the borehole during use of the apparatus and may include a rupturable member such that after the secondary sleeve has been located in the apparatus to close the at least one fluid port, the rupturable member may be ruptured by fluid pressure within the throughbore to permit flow of fluid through the throughbore in the apparatus. In this example, the secondary sleeve may include a releasable locking mechanism to releasably lock the secondary sleeve to the apparatus.

Examples of apparatus for circulating fluid in a borehole in accordance with the invention will now be described with reference to the accompanying drawings, in which:-

Fig. 1 is a cross-sectional view through one half of a first example of apparatus for circulating fluid in a borehole;

Fig. 2 is a schematic diagram showing an indexing slot and support surfaces of the apparatus shown in Fig. 1; and

Fig. 3 is a cross-sectional view through one half of a second example of apparatus for circulating fluid in a borehole.

Fig. 1 shows apparatus 1 for circulating fluid in a borehole. The apparatus 1 comprises an outer body member 2 having a jet port 3 and an exhaust port 4. Mounted within the body member 2 is a seal housing 5 to which is connected a travel pin mounting member 6 in which a travel pin 7 is mounted. Above the travel pin mounting 6 are two thrust bearings 8 between which a return spring 9 is located. The exhaust port 4 communicates between the outside of the body member 2 and void 10 in which the return spring 9 is located. Mounted on the upper thrust bearing 8 is a piston ring 11 to which a piston sleeve 12 is threadedly mounted. The piston sleeve 12 extends past the void 10, pin mounting member 6 and terminates adjacent to the seal housing 5. In the piston sleeve 12, adjacent the seal housing 5 is a piston sleeve port 13. The void 10 is isolated from the central throughbore 14 of the apparatus by seals 15, 16. Hence, the void 10 is only exposed to pressure externally of the body member 2. Therefore, the combination of the piston ring 11 and piston sleeve 12 acts as a differential piston operating on the pressure differential between the throughbore 14 and the outside of the body member 2. In the outside surface of the piston sleeve 12 is an indexing slot 17 which co-operates with travel pin 7 to form an indexing mechanism. In addition, support

surface 18 on the seal housing 5 co-operates with a support surface 19 on the piston sleeve 12 such that loads between the piston sleeve 12 and body piece 2 are not borne solely by the travel pin 7 and slot 17 but are borne primarily by the support surfaces 18, 19. This has the advantage of reducing fatigue of the travel pin 7.

The indexing slot 17 and support surfaces 18, 19 are shown in more detail in Fig. 2. The indexing slot 17 comprises: three closed positions 17a in which the sleeve 12 obturates the fluid port 3 when the travel pin is in the position 17a; an open position 17b in which, when the pin moves to the position 17b, the piston sleeve port 13 aligns with the fluid port 3 to permit fluid communication from the throughbore 14 to outside the apparatus 1 through the ports 3, 13; and, four rest positions 17c which correspond to the position occupied by the travel pin 7 when there is no fluid flow or pressure in the throughbore 14. The slot 17 is continuous around the outside of the piston sleeve 12.

Although not shown in detail in Fig. 2, the slot 17 is configured to permit movement of pin 7 relative to the slot 17 in only one circumferential direction to prevent the pin 7 reversing to a previous position. The geometrical configuration of the slot 17 would be well known and obvious to a person skilled in the art.

It can be seen from Fig. 2 that the support surfaces 18, 19 are configured such that when travel pin 7 is in one of the positions 17a, surface portions 19a of the piston support surface 19 abut against surface portions 18a of the seal housing support surface 18. When the travel pin 7 is located in the position 17b in the

indexing slot 17, surface portions 19a in the piston support surface 19 abut against surface portions 18b on the seal housing support surface 18 and surface portions 18a on the seal housing support surface 18 abut against surface portions 19b on the piston support surface 19. The indexing slot 17 and the support surfaces 18, 19 are configured such that when the travel pin 7 is located in position 17a or 17b, the primary loading between the sleeve 12 and seal housing 5 is borne by the support surfaces 18, 19 rather than the travel pin 7.

In use, the apparatus 1 is coupled into a portion of drillstring and lowered into a borehole with the sleeve 12 in the position shown in Fig. 1.

When fluid, such as drilling fluid or mud is pumped through the drillstring, the fluid will flow through the throughbore 14 in the apparatus 1 and the pressure differential between the throughbore 14 and the annulus between the outside of the body member 2 and the inside surfaces of the borehole will cause the piston 12 to move downwards and the travel pin 7 to move to position 17a. Each time pumping of the fluid into the drillstring is stopped, the differential pressure will be relaxed from the piston 12 and the travel pin 7 will return to the rest position 17c. When it is desired to circulate fluid out of the apparatus 1 through the jet port 3, the drilling fluid is stopped and restarted repeatedly until the travel pin 7 moves to position 17b in the indexing slot 17. When the travel pin 7 moves to position 17b, the port 13 in the piston sleeve 12 aligns with the jet port 3 to permit fluid to pass into the annulus between the outside surface of the body member 2 and the inside surface of the borehole through ports 3, 13. This permits all of, or a proportion of,

the drilling fluid to be circulated to the surface without passing through the drillbit at the end of the drillstring, and facilitates flushing out of any drill cuttings located in the borehole above the position of the jet ports 3.

It is possible that nozzles may be incorporated into the ports 3 to facilitate only a proportion of the drilling fluid to exit the apparatus through the ports 3. This feature would have the advantage of permitting the remaining proportion of the fluid to pass down through the BHA and out of the drill bit. This may be particularly advantageous during certain drilling operations, such as coring. The nozzles may be removable or replaceable and may be available in a number of orifice sizes. This would permit an operator of the apparatus to choose the proportion of fluid that is diverted out of the apparatus 1 through the jet ports 3.

Fig. 3 shows apparatus 20 for circulating fluid in a borehole. The apparatus 20 is similar to the apparatus 1 shown in Fig. 1, except that the apparatus 20 has a secondary inner sleeve 21 located within the piston sleeve 12 and the secondary sleeve 21 is secured to the sleeve 12 by a shear pin 22. In addition, the secondary sleeve 21 has a port 23 in its side wall which is aligned with fluid port 13 in the piston sleeve, when the secondary sleeve 21 is secured to the piston sleeve 12 by the shear pin 22.

In normal operation, the apparatus 20 operates identically to the apparatus 1 shown in Fig. 1.

However, in the event that for some reason it is not possible to return the piston sleeve 12 from the open

position to the closed position (ie. return the travel pin from position 17b to position 17a) then an extrudable spherical ball may be dropped down the drillstring into the apparatus 20. Typically, the extrudable ball may be manufactured from a plastic, an elastomeric or a rubber material. When the ball is dropped into the piston sleeve 12, it rests on upper shoulder 25 of the secondary sleeve 21. In this position fluid flow from the throughbore 14 out of the jet ports 3 is prevented by the ball. When the fluid pressure above the ball is increased, this causes shear pin 22 to shear and the secondary sleeve 21 moves downwards relative to the piston sleeve 12 until shoulders 26, 27 abut against each other. In this position, the port 23 is clear of the bottom end of the piston sleeve 12 and further pressure above the extrudable ball causes the ball to move down within the secondary sleeve 21 until it butts against a lower shoulder 24 in the piston sleeve 21. In this position fluid is permitted to flow from the throughbore into the piston sleeve 21 and exit from the piston sleeve 21 via the ports 23.

Hence, the apparatus 20 permits drilling operations to be continued even if it is not possible to return the piston sleeve 12 from the open to the closed position and permits drilling operations to be continued without requiring retrieval of the drillstring to the surface in order to correct the problem.

As an alternative to the sleeve 21 it would be possible to use a sleeve with no ports 23 and a burst disc located at one end. This sleeve could be dropped into drillstring from the surface in the event that it is not possible to return the sleeve 12 from the open to the closed position. The sleeve with the burst disc

would then obturate the port 13 when it fell into position within the piston sleeve 12. The burst disc may then be burst by increasing fluid pressure in the throughbore 14 to permit fluid to flow through the sleeve and permit normal drilling operations to continue.

Advantages of the invention are that it permits circulation of fluid in a borehole without requiring the fluid to pass through the drill bit and provides an indexing mechanism to permit repeated operation of the tool to facilitate circulation of fluid through the side walls of the tool or alternatively to close the tool and continue drilling operations.

In addition, the invention may also be used in well control situations as it would be possible to use the apparatus to introduce heavy mud above an influx of gas and/or oil to control the influx.

A further advantage is that the apparatus shown in Figs. 1 and 3 uses differential pressure between the throughbore 14 of the apparatus 1, 20 and the external pressure outside the apparatus in order to move the piston sleeve 12 from the closed to the open positions and from the open to closed positions. In addition, the use of an indexing mechanism permits the sleeve to be retained in the closed or open position irrespective of the flow rate of fluid through the throughbore 14, provided that the pressure in the throughbore is greater than the pressure externally off the tool.

Modifications and improvements may be incorporated without departing from the scope of the invention.

CLAIMS

1. Apparatus for circulating fluid in a borehole comprising a body member adapted to form a portion of a length of drillstring, the body member having a throughbore therein, and a fluid port extending through a side wall of the body member; an inner sleeve movably mounted within the body member for movement between a closed position in which the inner sleeve obturates the fluid port and an open position in which the fluid port is permitted to communicate with the throughbore; a pressure differential means to generate a pressure differential across the inner sleeve to move the sleeve from the closed to the open position in use; and, an indexing mechanism which couples the inner sleeve to the body member to permit the inner sleeve to be selectively moved between the closed position and the open position and to maintain the inner sleeve in the closed or open position.

2. Apparatus according to claim 1, wherein the pressure differential means is provided by the inner sleeve which is in the form of a differential pressure piston.

3. Apparatus according to claim 2, wherein the pressure differential means also comprises sealing means to isolate a surface area of the piston exposed to pressure from outside the body member from a surface area of the piston exposed to fluid pressure in the throughbore.

4. Apparatus according to claim 1, wherein the pressure differential means comprises a restriction in the throughbore.

5. Apparatus according to any of the preceding claims, wherein the inner sleeve obturates the fluid port in the closed position and another fluid port through the inner sleeve aligns with the fluid port in the body member when the inner sleeve is in the open position.

6. Apparatus according to claim 5, wherein a number of fluid ports are located circumferentially around the body member and the inner sleeve.

7. Apparatus according to any of the preceding claims, wherein the indexing mechanism includes a number of sequential indexing positions.

8. Apparatus according to claim 7, wherein there are a number of indexing positions in which the inner sleeve is in the closed position and one indexing position in which the sleeve is in the open position.

9. Apparatus according to claim 7 or claim 8, wherein the indexing mechanism comprises a slot or groove formed on the outside surface of the inner sleeve which cooperates with a pin mounted on the body member.

10. Apparatus according to any of the preceding claims, wherein the fluid port includes a restriction.

11. Apparatus according to claim 10, wherein the restriction is removable or replaceable.

12. Apparatus according to any of the preceding claims, wherein the inner sleeve moves in a direction parallel to a longitudinal axis of the throughbore and rotates relative to the body member during movement from the closed position to the open position.

13. Apparatus according to any of the preceding claims, wherein the apparatus further comprises a secondary inner sleeve movably mounted within the inner sleeve, the second inner sleeve being moveable relative to the inner sleeve to close the fluid port when the inner sleeve is in the open position.

14. Apparatus according to claim 13, wherein the secondary sleeve is moved to close the fluid port by dropping a member from the surface of the borehole into the throughbore so that the member engages with the secondary inner sleeve.

15. Apparatus according to claim 13, wherein the secondary sleeve is inserted into the apparatus from the surface of the borehole through the drillstring, during use of the apparatus.

16. Apparatus according to claim 15, wherein the secondary sleeve includes a rupturable member such that the secondary sleeve may be pumped by fluid pressure into position in the apparatus to close the fluid port and excess fluid pressure above the member ruptures the rupturable member to permit fluid flow through throughbore in the apparatus.

17. Apparatus according to claim 15 or claim 16, wherein the secondary sleeve includes a releasable locking mechanism to lock the secondary sleeve to the apparatus when the secondary sleeve closes the fluid port.

18. Apparatus substantially as hereinbefore described with reference to the accompanying drawings.

The Patent Office

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Application No: GB 9701599.4
Claims searched: 1 to 18

Examiner: David Harrison
Date of search: 13 February 1997

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.O): E1F (FGL, FLP)

Int Cl (Ed.6): E21B

Other:

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
X,E	GB 2302895 A	(Phoenix P.A. Ltd.) 5 February 1997; Whole document	1-7,9,12
X	GB 2006853 A	(Halliburton Company) Whole document	1-3,5-9
X	EP 0223552 A2	(Halliburton Company) Whole document	1-3,5-9
X	EP 0063519 A2	(Schlumberger Technology Corporation) Whole document	1-3,5-9
X	US 4298077	(Emery) Whole document	1-7,9,12

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